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RISK ASSESSMENT FOR NEW SLIP CONSTRUCTION, WAUKEGAN HARBOR, ILLINOIS

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EXECUTIVE SUMMARY

A risk assessment was conducted to evaluate whether the proposed construction of a new slip at the northern end of Waukegan Harbor would result in adverse effects to the public or the environment. Analysis of soil samples from the proposed location of the new slip and surrounding areas detected elevated levels of polycyclic aromatic hydrocarbons (PAHs) in soils at depths of 5 and 15 feet, but PAHs were not detected in soils or ground water samples collected at a depth of 25 feet. Phenolic compounds were detected in the deep soil samples and the ground water at 25 foot depths, but were not detected in the shallower samples. These constituents are probably the result of past operations at a coke facility located at the site until the 1970s.

The proposed new slip is intended to service a marina located at the north end of Waukegan Harbor, providing an area for docking and removing boats for service or storage. The depth of the slip will be approximately 15 feet. The north and south sides of the slip as proposed, will be lined with sheet metal pilings and the eastern end will be beached. The bottom of the slip will be natural soils.

The risk associated with the new slip was assessed in terms of increased potential for exposure to the PAHs or phenolics as a result of the slip construction and operation. Construction of the slip could result in an increased potential for exposure because of increased activity at the site, transport of subsurface soils to the surface, direct contact between subsurface soils and waters of the slip, and increased seepage of ground water into the slip and harbor as a result of the beached end and natural soil slip bottom.

Five potential exposure pathways and receptors are representative of the conditions associated with the slip construction and operation. These are: (1) direct contact with surrounding soils and waters of the slip by boatyard workers; (2) direct contact exposure with soils slip waters by visitors to the marina; (3) direct contact with subsurface soils by a utility worker relocating the existing sewer line; (4) direct contact with soils removed from the new slip and spread or stored on the undeveloped property adjacent to the slip; and (5) ingestion of fish caught in the vicinity of the new slip.

Based on estimates of reasonable exposure conditions resulting from the new slip, potential levels of exposure and risks to the public are within acceptable guidelines. Worst-case exposure assessments using the maximum concentrations detected in the soils result in elevated levels of risk to the boatyard worker or marina visitor. However, mean concentrations representative of overall site exposure result in levels of risk within acceptable guidelines.

Concentrations detected in soil samples collected at a 15-foot depth are assumed to be representative of concentrations of PAHs that would be present as sediment in new slip. Estimates of potential surface-water quality were made based on these sediment concentrations and partition coefficients for the PAHs. Potential concentrations of phenols in the harbor surface water were estimated based on modeling of the increased rate of ground-water seepage (approximately 10 percent) to the slip. Comparison of these estimated surface water and sediment concentrations with federal water quality criteria and interim sediment criteria from the U.S. Environmental Protection Agency indicated that potential concentrations at the new slip would be below concentrations considered protective of freshwater aquatic life. The available data provides evidence that impacts to aquatic life in Waukegan Harbor as a result of the new slip are unlikely.

In general, the concentrations of PAHs and phenols detected at the site could result in levels of human exposure that are acceptable under current guidelines. The likelihood of adverse impacts to the environment is low based on the estimated concentrations and what is presently known regarding the effects of these constituents on aquatic ecosystems.

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1.0 INTRODUCTION

The objective of this risk assessment is to evaluate potential risks to the public or the environment that would result from the construction of a new slip at the northern end of Waukegan Harbor. Analysis of soil samples collected from the site of the proposed new slip area detected several constituents believed to be associated with the past operation of a coke facility which was operated in the area for a number of years. This risk assessment is conducted to evaluate the factors associated with the siting of and construction of the new slip.

This report is not predicated by regulatory requirements; however, the methodology used to quantify exposure and risk levels are consistent with the methodology developed by the U.S. Environmental Protection Agency in the "Superfund Public Heath Evaluation Manual" (USEPA, 1986a). The quantification of potential exposure levels is based on the analytical results of soil and ground-water samples collected by Canonie Environmental in 1989.

2.0 SITE CHARACTERIZATION

The proposed location of the new slip is at the northern end of Waukegan Harbor in Waukegan, Illinois. The site of the proposed new slip is on property currently owned by Outboard Marine Corporation (OMC). The site was previously owned by General Motors, who operated a coke facility at the site until the late 1970s, when the property was purchased by OMC and the buildings and structures were removed.

Waukegan Harbor is a 42-acre, irregularly shaped arm of Lake Michigan located approximately 37 miles north of Chicago, Illinois. In addition to OMC, other facilities located in the area include Larsen Marine, a National Gypsum plant, Falcon Marine, and the Waukegan Water Filtration plant. A public beach is located at the eastern edge of the OMC property. Public launching ramps, mooring sites, slips, and other facilities for small boats are also located in the harbor, primarily in the southern portion. The entire harbor, with the exception of the boat launching areas of the Waukegan Port District, is surrounded by long steel sheet pilings which are 6 to 8 meters in length and generally do not extend into the sand underlying the glacial till.

The proposed new slip will be used in the operation of the Larsen Marine marina. The harbor is formed by a peninsula of land extending southward from the OMC facility and marina. The proposed new slip is located at the northern end of the harbor peninsula (Figure 1).

The depth of the new slip as proposed will be approximately 15 feet below existing grade, with sheet metal pilings on the northern and southern sides of the slip, and an open beached surface at the eastern end. The bottom of the slip will be natural soils. The bottom of the existing harbor is typically a soft organic silt (muck) ranging from 0.3 to 1.8 meters deep.

The shallow ground-water aquifer at the site is composed of approximately 25 feet of coarse sands. Seventy-five feet of glacial till (clay) separates the shallow unconfined aquifer from a deeper artesian aquifer. Regional ground-water flow in the shallow aquifer is toward Lake Michigan; however, Waukegan Harbor separates the shallow aquifer on the peninsula from the regional flow. The local flow on the peninsula is from the center of the peninsula toward the harbor and lake, respectively. There is no ground-water withdrawal ans use from the shallow aquifer at the site.

3.0 CONSTITUENT CHARACTERIZATION

3.1 OCCURRENCE

This section summarizes available information about the occurrence of constituents in soil and ground water. Constituents are grouped into three categories: phenolics, carcinogenic polycyclic aromatic hydrocarbons (cPAHs), and total polycyclic aromatic hydrocarbons (tPAHs).

3.1.1 Occurrence in Soils

Soil samples were collected in the new slip area during July and August 1989. Thirty-three borings were drilled and samples were taken at depths of 5 feet, 15 feet, and approximately 25 feet. Not all depths were sampled in all borings. The deeper samples were taken just above the clay. Samples S-42, S-43, S-49, S-52, S-56, S-65, and S-80 are located in the excavation area for the proposed new slip; the other samples were taken outside the proposed slip excavation area. Constituent concentration ranges and arithmetic and geometric means are provided in Table 1. PAHs were identified at the 5- and 15-foot depths, and phenolics were identified in the deeper soil samples (25 feet) within the slip area. The constituents identified in samples include: phenolics (phenol, 2-methylphenol, 4-methylphenol, and 2,4-dimethylphenol); cPAHs; benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and dibenzo(a,h)anthracene); and non-carcinogenic PAHs (naphthalene, 4-chloroaniline, 2-methylnaphthalene, acenaphthalene, acenaphthene, dibenzofuran, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, and benzo(g,h,i)perylene). The high end of the ranges and the arithmetic and geometric means are higher for samples outside the proposed slip area than for those taken within the slip excavation area.

3.1.2 Occurrence in Ground Water

Two shallow monitoring wells (15 feet) and two deep monitoring wells (25 feet) were sampled during October 1989. Constituent concentrations are provided in Table 2. PAHs (naphthalene, 2-methylnaphthalene, acenaphthene, fluorene, and phenanthrene) were identified in one shallow well (MW-1S) but not in deep wells. No cPAHs were identified in ground water. Phenolics (phenol, 2-methylphenol, 4-methylphenol, and 2,4-dimethylphenol) were identified in both deep wells.

3.2 PHYSICAL AND CHEMICAL PROPERTIES

The fate and transport of constituents are affected by their physical and chemical properties. Table 3 lists some of these properties for PAHs and phenolics. Information for PAHs is applicable to both carcinogenic and non-carcinogenic PAHs.

The physical and chemical properties considered in this report include: water solubility, specific gravity, vapor pressure, Henry's Law Constant, organic carbon distribution coefficient (K_{OC}), octanol-water partition coefficient (K_{OW}), fish bioconcentration factor, and half-life. Water solubility is the maximum or saturated concentration of a chemical in pure water at a specific temperature. Specific gravity is the ratio of the density of a chemical to the density of water. Vapor pressure is a property of a chemical in its pure state and is an important indication of the volatility of a chemical. Henry's Law Constant is the air/water partition coefficient of a chemical which relates its concentration in the gas phase to its concentration in the water phase. It can be used to calculate the rate of evaporation of a chemical from water. K_{OC} is a measure of the tendency for organic chemicals to be adsorbed by soil and sediment; K_{OW} is a measure of the distribution of a chemical, at equilibrium, between octanol and water. The fish bioconcentration factor (BCF) is a measure of the tendency for a chemical in water to concentrate in fish tissue. The half-life ($T_{1/2}$) is the time required for the concentration of a chemical to be reduced by a factor of two.

3.2.1 Polycyclic Aromatic Hydrocarbons

PAHs generally adsorb strongly onto soil particles and suspended particulates. Because of extremely low vapor pressures, volatilization is not an important fate process. In general, as molecular weight increases, water solubility tends to decrease such that naphthalene is more soluble in water than benzo(b,k)fluoranthene. PAHs dissolved in ground water would remain relatively intact due to slow degradation rates and limited volatilization. Biodegradation and biotransformation are the predominant mechanism for PAH degradation in soil and sediment. Upon release to surface water, PAHs will undergo rapid photolysis. PAHs are readily bioaccumulated; however, they are also rapidly metabolized and excreted. The dominant transport process for PAHs is associated with adsorption to soil, suspended particulates, and sediments; once absorbed, transport of PAHs would be limited (USEPA, 1979).

3.2.2 Phenolics

Biodegradation is the most significant removal mechanism for phenol from aquatic systems and soil (Howard, 1989). Although direct photolysis of phenol can occur, this process appears to be of minor importance compared with biodegradation. Phenol is expected to evaporate, hydrolyze, adsorb to sediment, or bioconcentrate in aquatic organisms based upon the relatively low octanol/water partition coefficient and the available experimental evidence (Howard, 1989). Volatization of phenol from surface water is possible; however, any significant atmospheric transport is not likely since photoxidation would occur (USEPA, 1985).

3.3 TOXICOLOGICAL PROPERTIES

The risks associated with exposure to constituents detected in the slip area are a function of the inherent toxicity (hazard) of the constituents and the exposure dose. This section addresses the inherent toxicological properties of the constituents. The exposure doses are estimated in the Exposure Assessment section which follows.

A distinction is made between carcinogenic and non-carcinogenic effects, and two general criteria are used to describe risk: excess lifetime cancer risk (for contaminants which are thought to be potential human carcinogens) and the hazard index (HI) (for all contaminants). For potential carcinogens, the current regulatory guidelines use an extremely conservative approach in which it is assumed that any level of exposure to a carcinogen could hypothetically cause cancer. This is contrary to the traditional approach to toxic chemicals, in which finite thresholds are said to exist, below which the toxic effect will not occur. This traditional approach is still applied to non-carcinogenic chemicals. Because of these differing approaches to calculating risk, the potential risks associated with carcinogenic effects are generally much higher than those associated with non-carcinogenic effects. Table 4 summarizes the recognized toxic responses associated with carcinogenic and non-carcinogenic PAHs and phenolics. Detailed toxicity profiles for carcinogenic PAHs and non-carcinogenic PAHs are located in Appendix A.

3.3.1 Carcinogenic Effects

Cancer is thought to be the end result of a multistage process in which a large number of biological and environmental factors interact, simultaneously or in sequence, to disrupt normal cell growth and division. The first stage, called initiation, involves the creation of errors in genetic coding. Because the effects of initiation are thought to occur at the molecular level, current regulatory policy assumes that there is no finite dose below which the initiation effect cannot occur. In other words, at any dose there is some finite probability associated with the occurrence of the initiation event.

Once a cell is initiated, many other processes affect the development of cancer; any one of these processes can also block the development of cancer. Therefore, the frequency of cancer occurrence is very low in comparison to the hypothetical frequency of initiation events. Further, many chemicals which are classified as "carcinogens" probably do not actually initiate cancer, but rather act at a later stage on cells which were already initiated. Although these chemicals are treated as if one molecule could cause significant damage, this almost certainly is not true.

Identification of constituents which are included in the carcinogen category is based on a USEPA classification scheme in which chemicals are systematically evaluated for their ability to cause cancer in mammalian species, and conclusions are reached about the potential to cause cancer in humans. The USEPA classification scheme contains six categories based on the weight of available evidence: A (human carcinogen), B1 (probable human carcinogen -- limited evidence in humans), B2 (probable human carcinogen -- inadequate evidence in humans), C (possible human carcinogen), D (inadequate evidence to classify), and E (no evidence of carcinogenicity). Categories A, B1, B2, and C are included in this assessment as potential human carcinogens. Much of the USEPA's evaluation is based on laboratory animal studies. In order to limit the number of animals required for testing, very high doses of chemicals are used in laboratory studies. For chemicals which seem to cause or increase cancer, the results of these high-dose animal studies are extrapolated to the low-dose human exposure situation using mathematical models. However, these models do not depict biological reality. A variety of mathematical models are available for extrapolating from high to low doses; however, the USEPA currently favors a linearized multistage model which provides a 95 percent upper-bound estimate of cancer incidence at a given dose. The slope of the extrapolated curve, called the carcinogen potency factor, is used to calculate the probability of cancer associated with an exposure dose. (Exposure doses are derived in the Exposure Assessment section.) The probability of developing cancer as a result of exposure to contaminants associated with the facility is called the excess lifetime cancer risk and is the product of exposure dose and carcinogen potency factor. Excess lifetime cancer risk is expressed in terms of the predicted number of cancer cases occurring above background incidence per number of individuals exposed (i.e., one in a million or 1×10^{-6}).

The excess lifetime cancer risk is an estimate of the increased risk of cancer which results from exposure to constituents associated with the proposed new slip construction. Approximately one out of four Americans will have cancer during their lifetimes, and about half of those will die from the cancer (Goehring, 1989). The risk values provided here are an indication of the increased risk, above that applying to the general population, which results from the exposure scenarios described in the Exposure Assessment section. The actual cancer risk is unknown and could be anywhere between zero (no risk of cancer) and the value that is provided, but it is not likely to exceed the estimate derived in this risk assessment. Excess lifetime cancer risk can be summed across routes of exposure and constituents.

An excess lifetime cancer risk of greater than 10^{-4} is generally considered unacceptable. Excess lifetime cancer risks in the range of 10^{-4} to 10^{-7} are potentially acceptable (50 FR 219). A range of 10^{-4} to 10^{-7} is the common target for remediation activities.

3.3.2 Non-Carcinogenic Effects

A finite dose (threshold), below which adverse effects will not occur, is believed to exist for non-carcinogenic effects. These include birth defects, organ damage, death, and many other health impacts. A single compound might elicit several adverse effects depending on the dose, the route, and the duration of exposure. For a given chemical, the dose which elicits no effect when evaluating the most sensitive response (the adverse effect which occurs at the lowest dose) in the most sensitive species is used to establish an acceptable dose for non-carcinogenic effects. Acceptable doses which are sanctioned by the USEPA are called verified reference doses (RfDs). It is the most sensitive response in the most sensitive species which is the determinant of whether exposure is acceptable.

The Hazard Index (HI) is used to evaluate non-cancer health effects of compounds and is the ratio of the exposure dose to the acceptable dose or RfD. An HI greater than one is an indication that exposure is too high; it means that, for a given contaminant, exposure exceeds acceptable levels for protection against non-cancer effects. HIs can be calculated for each contaminant and summed across exposure routes for all media at the facility. Although an HI of less than one suggests that non-cancer health effects would not occur, some regulatory agencies prefer that the HI be less than 0.2; this preference is based on the realization that people may be exposed to these same constituents from sources unrelated to a specific site.

3.3.3 Toxicity Values

In general, cancer potency factors (CPF), carcinogenicity classifications, and RfDs (separated by exposure route) are taken from USEPA's Superfund Public Health Evaluation Manual (1986a), the Integrated Risk Information System (IRIS) (an EPA-approved computer data base), or the most recent Health Effects Assessment Document (USEPA, 1989a). Three routes of exposure are considered: dermal (skin), inhalation, and ingestion. Whenever possible, route-specific values are used. Because acceptable levels for dermal exposure are virtually never available, oral values are used in their place. When inhalation values are not available, oral values are substituted in their place, unless compound-specific information clearly indicates that this would be inappropriate. In some cases, route of exposure determines the type of toxicity that will be expected. Table 5 provides RfDs, carcinogenicity classifications, and CPFs for cPAHs, tPAHs and phenolics. Table 4 summarizes the toxicity of constituents.

For purposes of evaluating risks associated with constituents detected in soil and ground water in the slip area, the PAHs were divided into carcinogenic PAHs and total PAHS as described in Sections 3.1.1 and 3.1.2. There are very few RfDs that have been accepted by the USEPA for PAHs. The USEPA has estimated the CPF for only one PAH, benzo(a)pyrene, and this compound will be used as a surrogate in estimating the potential risks from exposure to carcinogenic PAHs in general. In the absence of any USEPA-verified RfDs for the carcinogenic PAHs detected at this site, the

RfD for naphthalene will be used to estimate hazard indices for total PAHs. Data for phenol are used to represent phenolics.

3.4 STANDARDS OR CRITERIA

Applicable standards or criteria for the cPAHs, tPAHs, and phenolics are listed in Table 6. These are federal and/or state standards and criteria for sediments and surface water. There are no available standards applicable for soils.

4.0 EXPOSURE ASSESSMENT

This section addresses the potential for exposure to the PAHs and phenolics detected in the soils and ground water in the vicinity of the new slip. In order for risk to exist, the potential for a receptor to be exposed to released chemicals must exist. Exposure can only occur if there is both a source of chemical release and a mechanism of transport to a receptor population.

4.1 RELEASE/SOURCE ANALYSIS

The initial sources of the constituents detected in the soil and ground water were the past operations of a coke facility located at the site. At present, based on the sampling results, the PAHs are primarily associated with the soils and the phenolics being less strongly adsorbed to soils are associated with both the deep subsurface soils and the ground water.

Release pathways for the PAHs and phenolics under existing conditions are primarily leaching to the ground water and seepage to Waukegan Harbor. The PAHs are not highly volatile and the phenols are located in the deeper (25 foot) soils and ground water; therefore, volatilization is not a significant transport route. Fugitive dust emissions are possible for the PAHs remaining in the surficial soils.

Construction of the new slip would not eliminate any of the existing pathways, but could result in some additional release pathways. Excavation of the soils from the slip area could result in the transport of subsurface concentrations of PAHs to the surface for possible fugitive dust transport. The bottom of the slip will be in direct contact with surface waters of the slip, so that what are presently subsurface soils will become sediments in the new slip. Although the PAHs are highly adsorbed to soils and have exhibited limited migration potential (low detection in ground water), subsurface concentrations of PAHs will now be in direct contact with the surface waters.

Regional ground-water flow is toward Lake Michigan. The new slip location is on a peninsula of land with Lake Michigan to the east and Waukegan Harbor to the west. The shallow regional ground-water flow is blocked by Waukegan Harbor. The hydraulic gradient on the peninsula is assumed to be governed by infiltration recharge rates, and flow is toward either the lake or the harbor. The harbor is lined with sheet metal pilings that may retard the flow rate but are not impermeable. Under existing conditions prior to the construction of the new slip, ground-water flow to the harbor is relatively lower than toward the unrestricted lake/ground-water interface. Based on the results of a one-layer numerical slip (Appendix B), the flux of ground water into the harbor under existing conditions is 43.2 gallons per minute (gpm). The addition of the slip could potentially increase the flux of water into the harbor to 47.7 gpm, an increase of 4.5 gpm. The proposed new slip would only increase ground-water flow into the harbor by approximately 10 percent.

In general, the release pathways for the PAHs and phenolics are the same as presently exist with the difference that subsurface concentrations of PAHs would be directly exposed to the surface waters and on the land surface, and the rate of seepage of ground water into the harbor from the immediate vicinity of the new slip may be increased.

4.2 EXPOSURE PATHWAYS, EXPOSURE POINTS, AND RECEPTORS

The potential exposure pathways, exposure points, and receptors are listed in Table 7. The primary exposure pathways are associated with direct exposure to the PAH concentrations in the subsurface soils that would be exposed to the surface. The primary point of exposure is the area immediately surrounding the slip, Waukegan Harbor, and the undeveloped OMC property where the soils removed from the slip may be spread or stored.

The potential human receptors include boatyard workers, OMC employees, and visitors to the marina. The construction of the new slip will necessitate the relocation of the existing sewer line. One possible location for the new sewer line would be to the south and east of the new slip within the area of detected PAH concentrations. The utility employees relocating the sewer line are a possible receptor population. Additionally, a hypothetical receptor population consisting of consumers of fish from the harbor in the vicinity of the new slip was considered.

Potentially exposed environmental populations are primarily the aquatic life in Waukegan Harbor in the vicinity of the new slip. The PAHs are strongly adsorbed to soils and organic matter and are rapidly degraded by most biological organisms. Therefore, the principal exposure point for the PAHs in the slip sediments is the slip itself. Potential exposure to the phenolics is primarily associated with the seepage of ground water containing phenols into the beached end of the new slip.

4.3 EXPOSURE POINT CONCENTRATIONS

Potential exposure points resulting from construction of the new slip are as follows: (1) the surface water/sediments of the new slip; (2) the surficial soils surrounding the new slip; (3) the subsurface soils to the south and east of the new slip where the new sewer line may be located; (4) fish in the new slip or adjacent harbor; and (5) OMC undeveloped property south of the new slip where the excavated soils may be spread or stored. For estimating the potential exposure levels at these exposure points, estimates of concentrations at these points were made based on the available sampling data.

Two possible exposure point concentrations are utilized in estimating exposure levels. The most probable exposure levels are based on the mean concentration detected. Geometric means are utilized because of the high variability in the detected concentrations. Worst-case exposure levels are estimated using the maximum concentrations detected. These worst-case estimates are used as an upper bound on quantified exposure levels, whereas the most probable exposure levels are the levels of primary concern in assessing risks.

1.7 Use 15

Post-construction sediment concentrations in the slip were calculated from the seven soil samples which are located within the boundaries of the new slip at the 15-foot depth. The 15-foot depth was used because this is the approximate depth of the proposed new slip. The sediment concentrations for the most probable exposure scenario are 1.1 mg/kg and 3.2 mg/kg for the cPAHs and tPAHs, respectively. The worst-case sediment concentrations are 6 mg/kg and 74 mg/kg for the cPAHs and tPAHs, respectively.

Surface-water concentrations for the PAHs are assumed to result from dissociation of the PAHs from the sediments. The partition coefficient (K_d) for the cPAHs (based on benzo(a) pyrene) is 55,000 mL/g, and 12.3 mL/g (based on naphthalene) for the tPAHs. These partition coefficients are based on a conservative assumption of a 1 percent organic carbon level; the reported organic carbon levels for samples collected at a depth of 20 feet are 1.5 to 2 percent. The estimated reasonable concentrations in the slip water (sediment concentration/K_d) are 2.0×10^{-5} mg/L for the cPAHs and 0.26 mg/L for the tPAHs. The worst-case slip water

B(a)P $\frac{1.7}{55,000}$ Napth $\frac{15}{12.3}$

concentrations are 1.1×10^{-4} mg/L for the cPAHs and 6.0 mg/L for the tPAHs, assuming equilibrium dissociation between the sediments and surface water.

Phenolics were not detected in the 15-foot soil samples. Discharge of phenolics to the surface waters is assumed to be primarily associated with the discharge of ground water containing phenols to the new slip. The proposed new slip is estimated to increase flow into the harbor by approximately 10 percent. The volume of water in the new slip is estimated to be approximately 6.3×10^{6} gallons (855,090 ft^3) based on a surface area of 57,006 ft^2 and an average slip depth of 15 feet. The half-life of phenols in surface waters is approximately 1 day (range of 0.62 to 9 days). Therefore, based on the relatively small increase in flow and the short persistence of phenols in surface water, the proposed new slip is assumed to result in insignificant levels of phenols in the harbor.

Estimated concentrations in the soils surrounding the new slip are assumed to be equal to the concentrations detected in the 5-foot soil samples collected from the area surrounding the slip. The mean concentrations for these surrounding soils are 13 mg/kg for the cPAHs and 64 mg/kg for the tPAHs. The worst-case surrounding soil concentrations based on the maximum reported concentrations are 3,110 mg/kg for the cPAHs and 25,750 mg/kg for the tPAHs.

Exposure point concentrations for the soils excavated from the slip were estimated as the mean of the concentrations detected in the seven 5-foot and seven 15-foot samples collected from the area inside the new slip. The mean concentrations for these soils is 1.2 mg/kg and 4.4 mg/kg for the cPAHs and tPAHs, respectively. The worst case excavated soil concentrations are 235 mg/kg and 840

→ possible point is Avg for ... outside slip mg/kg for the cPAHs and tPAHs, respectively. Phenolics were not detected in the 5-foot or 15-foot soil samples.

4.4 EXPOSURE DOSE CALCULATIONS

Average daily doses (ADDs) were calculated for each of the following potentially exposed populations: (1) boatyard worker, (2) marina visitor, (3) utility worker (sewer excavation), (4) OMC worker or trespasser, and (5) fisherman. Parameters used in quantifying the exposure levels are based on standardized assumptions (USEPA, 1988; USEPA, 1989) and professional judgment. Parameter assumptions and equations are summarized in the following sections. A conservative assumption underlying all these dosage calculations is that the constituent concentrations remain constant over the entire exposure period. Realistically, with the original source removed, the concentrations in the soils and ground water will be undergoing attenuation to lower concentrations. → very slowly

4.4.1 Boatyard Worker (Scenario 1)

Exposure of the boatyard worker is assumed to result from incidental contact with water and sediments from the new slip. Reasonable ADDs were calculated based on the following probable exposure assumptions: (1) a 70-kg adult (USEPA, 1988b); (2) in contact with soils or water from the slip 2 hours per day (hr/dy); (3) for 5 days per week, over a 16-week summer period, for a 5-year employment period; (4) over a 70-year lifetime; (5) incidentally ingests 10 mL of water/day and 10 mg of soil/day (USEPA, 1988b); (6) dermal adherence of soils to skin of 1.45 mg/cm^2 of skin (USEPA, 1988b); (7) flux of water through the skin of 0.5 mg/cm^2-hr (USEPA, 1988b); (8) exposed skin surface area of 2970 cm^2 (1/2 head and neck, and 2/3 upper limbs) (USEPA, 1989b); (9) a differential dermal absorption factor of 0.10 for organics

(USEPA, 1988b); (10) a soil matrix effect factor of 0.15 (Hawley, 1985); and (11) exposure is to mean concentrations detected. The equation used to calculate the reasonable ADD for the boatyard worker is shown in Table 8. The reasonable ADDs for the boatyard worker are listed in Table 9.

The differing assumptions used to calculate an upper bound worst-case ADD for the boatyard worker are as follows: (1) the 70-kg worker is in contact with the soil and water for 8 hrs/dy; (2) for 5 days per week over the 16-week summer period for a 10-year employment period (USEPA, 1989b); (3) incidentally ingesting 10 mL of water and 100 mg of soil/day (USEPA, 1988b); (4) an exposed skin surface area of 6,210 cm^2 (1/2 head and neck, 2/3 upper limbs, 1/2 lower limbs) (USEPA, 1989b); and (5) exposure is to maximum concentrations detected. The equation used to calculate the worst-case ADD for the boatyard worker is shown in Table 8. The worst-case boatyard worker ADDs are listed in Table 9.

4.4.2 Marina Visitor (Scenario 2)

A conservative exposure scenario for the new slip assumes that children visiting the marina with their parents might wade (reasonable) or swim (worst case) at the beached end of the new slip. The parameter assumptions used to calculate the reasonable ADDs are as follows: (1) a 31-kg child (9-yr old representative of 6- to 12-yr old period)(USEPA, 1989b); (2) wades in the new slip for 1 hour during 4 visits to the marina per year over a 6-year period; (3) incidentally ingesting 10 mL of water/visit, and 10 mg of soil/visit (USEPA, 1988b); (4) soil adherence of 1.45 mg/cm^2 over a skin surface area of 720 cm^2 (both feet) (USEPA, 1989b); (5) water flux of 0.5 mg/cm^2-hr, through a skin surface area of 3,105 cm^2 (1/2 head and neck, 2/3 upper limbs, and 1/2 lower limbs) (USEPA, 1989b); (6) differential dermal absorption factor of 0.10 for organics (USEPA, 1988b); (7) soil matrix effect factor of 0.15

(Hawley, 1985); and (8) exposure to the mean concentrations detected. The equation used to calculate the reasonable ADD for the marina visitor is shown in Table 8. The marina visitor ADDs are listed in Table 9.

The worst-case visitor exposure scenario assumes that the child is younger and swims in the slip along the beached end. The worst-case exposure assumptions that differ from the reasonable exposure scenario are as follows: (1) a 16-kg child (age 4; average between ages 4 to 6) (USEPA, 1989b); (2) swimming 4 hr/day; (3) once a week over the 16-week summer period over the 4-year age period; (4) ingesting 50 mL of water per hour while swimming and 200 mg of soil per visit (USEPA, 1988b); (5) dermal exposure while swimming of 7,000 cm^2 (whole body), and soil dermal contact area of 560 cm^2 (hands and feet) (USEPA, 1989b); and (6) exposure to the maximum concentrations detected. The equation used to calculate the worst-case marina visitor ADD is shown in Table 8. The marina visitor worst-case ADDs are listed in Table 9.

4.4.3 Utility Worker (Scenario 3)

The reasonable utility worker ADDs were calculated based on the following assumptions for a worker at an excavation site: (1) a 70-kg worker (USEPA, 1988b); (2) working in an excavation site along the slip for 2 hours a day over a 5-day period; (3) incidental ingestion of 10 mg of soil per day (USEPA, 1988b); (4) an average breathing rate of 1.3 m^3/hr (USEPA, 1988b); (5) exposed skin surface area of 2,970 cm^2 (1/2 head and neck and 2/3 upper limbs)(USEPA, 1989b); (6) dermal absorption factor of 0.10 for organics (USEPA, 1984); (7) soil matrix effect factor of 0.15 (Hawley, 1985); (8) suspended particulate matter concentrations of 0.075 mg/m^3 (53 FR 148); (9) fraction inhaled particulates of 0.125 (53 FR 148); (10) dust adherence of 1.45 mg/cm^2-day (USEPA, 1988b);

and (11) exposure to mean detected concentrations in the soils outside the new slip area. The equation used to calculate the reasonable utility worker exposure is shown in Table 10. The utility worker reasonable ADDs are listed in Table 9.

The worst-case utility worker exposure scenario differs from the reasonable scenario based on the following assumptions: (1) the worker is at the excavation site for 8 hr/day over a 20-day excavation period; (2) incidentally ingesting 100 mg of soil per day (USEPA, 1988b); (3) breathing rate of 2.8 m^3/hr (USEPA, 1988b); and (4) exposure to the maximum concentration detected in the soils outside of the new slip area. The equation used to calculate the worst-case utility worker exposure is shown in Table 10. The worst-case ADDs for the utility worker are listed in Table 9.

4.4.4 OMC Worker or Trespasser (Scenario 4)

Reasonable exposure to the soils excavated from the new slip area considers exposure of an OMC worker at the undeveloped OMC property where the soil is spread. The ADDs are calculated based on the following assumptions: (1) a 70-kg worker (USEPA, 1988b); (2) accessing the undeveloped property 4 times per year for 2 hours over a 10-year period; (3) incidentally ingesting 10 mg of soil per day (USEPA, 1988b); (4) dermal exposure over a 2,970 cm^2 skin surface area (1/2 head and neck and 2/3 upper limbs)(USEPA, 1989b); (5) an average breathing rate of 1.3 m^3/hr (USEPA, 1988b); (6) dust adherence of 1.45 mg/cm^2-day (USEPA, 1988b); (7) dermal absorption factor of 0.10 for organics (USEPA, 1984); (8) soil matrix effect factor of 0.15 (Hawley, 1985); and (9) exposure to the mean concentrations detected in the soil samples collected inside the slip. The equation used to calculate the reasonable OMC worker ADDs is shown in Table 10. The ADDs for the reasonable exposure scenario for an OMC worker is listed in Table 9.

The worst-case scenario for exposure to the excavated soils considers the exposure of a trespasser to the spread soils. The exposure assumptions that differ from the reasonable exposure scenario are as follows: (1) a 56-kg child (15-year-old; average of ages 12 to 18 (USEPA, 1989b); (2) trespasses for 2 hours on the undeveloped OMC property 6 times a year over the 6-year age period; (3) exposed skin surface area of 2,475 cm^2 (1/2 head and neck and 2/3 upper limbs) (USEPA, 1989b); (4) incidental soil ingestion of 100 mg per trespass (USEPA, 1988b); (5) breathing rate of 2.8 m^3/hr (USEPA, 1988b); and (6) exposure to the maximum concentrations detected in the soil samples form inside the slip. The equation used to calculate the ADDs for the trespasser exposure is shown in Table 10. The trespasser ADDs are listed in Table 9.

4.4.5 Fish Ingestion (Scenario 5)

Waukegan Harbor is presently posted warning against consumption of fish caught in the harbor due to PCBs in the sediments; however, hypothetical fish ingestion exposure is assessed to determine the potential impacts of the new slip if fish were ingested. The reasonably conservative assumptions used to calculate fish ingestion exposure are as follows: (1) a 70-kg adult (USEPA, 1988b); (2) ingesting an average of 6.5 grams of fish per day over a 70-year lifetime (USEPA, 1988b); (3) fraction of the total fish diet caught in the slip 0.10; and (4) the concentration of constituents in the edible fish tissue is equal to the product of the mean concentration estimated in the slip and the constituent specific BCF. The BCF reported for the carcinogenic PAHs range from approximately 100 to 1,000. For the reasonable exposure scenario, the BCF value of 100 is used because PAHs are rapidly metabolized in most aquatic organisms; the higher reported values are primarily based on shorter exposure periods in

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which depuration has not reached an equilibrium state. The equation used to calculate the ADDs for fish ingestion is shown in Table 11. The fish ingestion ADDs are listed in Table 9.

The worst-case exposure scenario for fish ingestion differs from the reasonable scenario in the following assumptions: (1) all fish in the diet are caught in the new slip; and (2) the concentrations in the edible fish tissue is the product of the maximum estimated in the slip and the bioconcentration factor. For the worst-case exposure the BCF for the cPAHs is assumed to be 1,000 L/kg which is at the top end of the estimated range. The equation used to calculate the ADDs for worst-case fish ingestion exposure is shown in Table 11. The worst-case fish ingestion ADDs are listed in Table 9.

5.0 RISK ASSESSMENT

Evaluations of potential risk are performed by using the ADDs from the previous section and the RfDs and CPFs identified in the section on toxicological properties to estimate the likelihood of adverse effects or risks to the exposed human populations. The likelihood of environmental risk is evaluated by comparison of projected exposure point concentrations to established environmental criteria.

Estimates of non-carcinogenic adverse effects are evaluated as the ratio of the ADDs to the RfDs. The ratio called the HI is generally considered acceptable if it is within the range of 0.2 to 1.0.

Excess lifetime cancer risks are calculated as the product of the ADD and the CPFs. Excess lifetime cancer risks represent hypothetical excess lifetime cancer incidences. Generally, the USEPA has used cancer risk levels in the range of 10^{-4} to 10^{-7} in decisions regarding acceptable levels of carcinogens. Concentrations which result in constituent excess lifetime cancer risks of 10^{-6} for reasonable exposure scenarios and worst-case scenario risks of less than 10^{-4}, are considered acceptable and protective of public health. NO!

5.1 PUBLIC HEALTH RISK

Five possible exposure scenarios were identified and evaluated in this report. The five exposure scenarios are based on the projected excavation of a new slip in the area identified in Figure 1. Potential risks identified are those new exposures resulting from the slip construction. Thus, the risks are associated with increased exposure to the soils and concentrations in the harbor resulting from increased release rates.

5.1.1 Boatyard Worker (Scenario 1)

The HI and excess lifetime cancer risks for reasonable exposure of a boatyard worker to the PAHs and phenols in the soils and slip waters are listed in Table 12. The HI for the tPAHs and phenols is 0.00018, well below 0.2. The excess lifetime cancer risk level is 2.3×10^{-6}, slightly greater than 10^{-6}, but well within the 10^{-4} to 10^{-7} guidelines.

Worst-case exposure of a boatyard worker would result in an HI of 0.14, and an excess lifetime cancer risk of 2.4×10^{-3}. The worst-case HI is less than 1.0, but the excess lifetime cancer risk is greater than 10^{-4}. Worst-case exposure of a boatyard worker could result in exposure levels exceeding acceptable guidelines if exposure to the maximum concentrations reported in the soils occurred.

5.1.2 Marina Visitor (Scenario 2)

The HI and excess lifetime cancer risks for reasonable exposure to a child visiting the marina and wading along the beached end of the new slip are listed in Table 12. The HI for exposure to tPAHs and phenols is 0.00067, and the excess lifetime cancer risk associated with the cPAHs is 7.8×10^{-8}. The HI and excess lifetime cancer risk for reasonable exposure of a visitor to the marina are well within acceptable guidelines.

Worst-case exposure of a small child visitor swimming in the new slip along the beached end resulted in an HI of 0.37 and an excess lifetime cancer risk of 2.4×10^{-4}. The worst-case HI for exposure of a marina visitor is less than 1.0· The worst-case cancer risk slightly exceeds 10^{-4}, and as with worst-case exposure of the boatyard worker, if exposure to the maximum concentrations detected in the soils were feasible then the exposure levels might exceed acceptable guidelines.

5.1.3 Utility Worker (Scenario 3)

The HI and excess lifetime cancer risks for reasonable exposure of a utility worker while excavating to the south and east of the new slip for installation of a new sewer line are listed in Table 12. The HI and excess lifetime cancer risks for exposure to PAHs are 0.00015 and 2.8×10^{-8}, respectively. The HI and excess lifetime cancer risk for reasonable exposure of a utility worker are within acceptable guidelines.

Worst-case exposure of the utility worker resulted in an HI of 0.073 and an excess lifetime cancer risk of 3.2×10^{-5}. The HI and excess lifetime cancer risk risk for worst-case exposure of a utility worker are within accceptable guidelines.

5.1.4 OMC Worker/Trespasser (Scenario 4)

The HI and excess lifetime cancer risks for exposure of an OMC worker to soil excavated from the new slip and spread on the undeveloped OMC property are listed in Table 12. The HI and excess lifetime cancer risk levels are 0.000011 and 2.0×10^{-8}, respectively. The HI and cancer risk levels are within acceptable guidelines.

Worst-case exposure of a trespasser at the undeveloped OMC property exposed to the excavated soils spread on the site resulted in an HI of 0.0025 and an excess lifetime cancer risk of 4.6×10^{-6}. The HI and cancer risk for exposure of a trespasser to the excavated soils are within acceptable guidelines.

5.1.5 Fish Ingestion (Scenario 5)

The HI and excess lifetime cancer risks for fish ingestion exposure are listed in Table 12. The HI and excess lifetime cancer risk levels are 0.000063 and 2.1×10^{-7}, respectively. The HI and cancer risk levels for reasonable fish ingestion exposure are within acceptable guidelines.

Worst-case fish ingestion exposure resulted in an HI of 0.015 and an excess lifetime cancer risk of 1.1×10^{-4}. The HI is within the acceptable guidelines, and the cancer risk levels are essentially equal to the acceptable guideline.

5.2 ENVIRONMENTAL RISKS

The proposed construction of the new slip is to support the operations of a very active marina. The slip will be used to dock and remove boats for service or storage at the marina. The new slip is not intended as an aquatic habitat. Therefore, this assessment is primarily concerned with the possibility of adverse effects to fish or aquatic organisms that might access the slip, but is not concerned with the slip as an ecosystem.

The federal water quality critiera for protection of freshwater aquatic life (as listed in Table 6) are 0.0012 for cPAHs (as benzo(a)pyrene), 0.62 mg/L for tPAHs (as naphthalene), and 2.56 mg/L for phenol. The estimated concentrations in the water of the proposed new slip based on the mean concentrations detected in the soils are 0.00002 mg/L for cPAHs, and 0.26 mg/L for tPAHs. The proposed new slip is estimated to increase ground-water flow into the slip by only 10 percent and not result in significant new discharge of phenols to the harbor. The estimated surface-water concentrations are lower than the chronic freshwater criteria.

Interim sediment quality critierion calculated by the USEPA for the cPAHs (as benzo(a)pyrene) was 1,063 mg/kg, and the criterion for the tPAHs (as pyrene) was 1,311 mg/kg (USEPA, 1988a). These interim sediment criteria concentrations are well above the maximum concentrations of PAHs that were detected in any of the soils samples. Thus, it is highly unlikely that sediment concentrations in the new slip could exceed the sediment criteria.

Based on the comparison of the federal water quality and sediment criteria with the estimated concentrations in the new slip, it is highly unlikely that aquatic organisms would be impacted from constituents associated with the new slip.

5.3 SITE-SPECIFIC SOIL CRITERIA

Health-based site-specific soil criteria were calculated for the proposed new slip area based on the potential exposure scenarios identified in Section 4.4. Based on the calculations of potential risk in Section 5.1, which values are listed in Table 12 for surficial soil concentrations, scenario 1 (boatyard worker) is the most sensitive scenario for the cPAH, and scenario 2 (marina visitor) is the most sensitive parameter for the tPAH and phenols. The equation listed in Table 8 was modified to back calculate an acceptable soil concentration (C_s) based on a cancer risk of 10^{-6} and an HI of 0.2. Scenario 3 (utility worker) is the most sensitive exposure receptor/pathway for calculation of a subsurface soil criteria. Equation 10 was modified to back calculate the subsurface soil criteria.

Using the most probable exposure parameters identified in Sections 4.4.1 and 4.4.2 and an exposure dose for cPAHs of 8.8×10^{-8} mg/kg/day (10^{-6}/cancer risk/11.3 cpf), for tPAHs of 0.08 mg/kg/day (0.4 [RfD] x 0.2 [HI]), and for phenols of 0.12

mg/kg/day (0.6 [RfD] x 0.2 [HI]), the site-specific soil criteria were calculated. The site-specific soil criteria for surficial soils are:

cPAH	6.0 mg/kg
tPAH	2,900 mg/kg

Using the same exposure doses and the parameters identified in Section 4.4.3, the subsurface soil criteria are as follows:

cPAH	480 mg/kg
tPAH	85,000 mg/kg

Concentrations of cPAHs and tPAHs at or below these concentrations in the soils will result in site specific excess lifetime cancer risk levels at or below 10^{-6} and HI at or below 0.2.

5.4 UNCERTAINTIES IN RISK ASSESSMENT

The risk estimates presented here represent very conservative overestimates of the actual risks associated with the creation of the new slip. Considerable uncertainty is inherent in the risk assessment process. Numerous assumptions and uncertainties are associated with the risk assessment presented in this report. There are three basic building blocks for the risk assessment: monitoring data, exposure scenarios, and toxicity values. Each contributes uncertainties.

This risk assessment is founded on the assumption that the monitoring data adequately describe media at the slip area. Environmental sampling itself introduces uncertainty, largely because of the potential for uneven distribution of constituents in environmental media. Two sampling methods, grab and composite, are typically used. Grab samples elucidate the distribution of constituents and the variation in concentrations. Composite samples indicate average constituent concentrations but can obscure information about "hot spots." Uncertainty associated with analysis of samples can be minimized by using appropriate analytical methods and equipment, documenting the chain of custody of samples, and implementing strict laboratory data validation, and quality assurance procedures. It is also critical that sample detection limits be lower than both the standards or criteria and the concentration which may present a health risk. The detection limits for data used in this assessment are acceptable. Characteristics of the matrix (medium) can also affect analytical results. In this case, it was not possible to sample media as they will exist following construction of the slip, so data for subsurface soils and ground water were used. Geometric means and maximum concentrations were used.

Constituent transport models and exposure scenarios also contribute uncertainty to the risk assessment. Transport models typically over-simplify reality, thus contributing uncertainty. For the slip area, ground-water flow through the beached end was estimated as were constituent concentrations in fish and expected concentrations of PAHs and phenolics in slip surface water. The exposure scenarios are also characterized by uncertainty, because the specific nature and extent of actual exposure are not known.

The toxicity values and other toxicologic (health effects) information used in this report are associated with significant uncertainty. Most health effects information has been developed using laboratory animals exposed to high doses. Although species differences in absorption, distribution, metabolism, excretion, and target organ sensitivity are well documented, available data are not sufficient to allow compensation for these differences. Most laboratory studies strictly control as many factors as possible, yet the human population is genetically diverse and affected by a variety of diets, occupations, pharmaceuticals, and other factors. (When human epidemiologic data are available, a different set of uncertainties is present. For instance, exposure dose is seldom well characterized in epidemiologic studies.)

There is also considerable uncertainty associated with the toxicity of mixtures. For the most part, data about the toxicity of chemical mixtures are unavailable. Rather, toxicity studies are generally performed using a single chemical. Chemicals present in a mixture can interact chemically to yield a new chemical or one can interfere with the absorption, distribution, metabolism, or excretion of another. Chemicals may also act by the same mechanism at the same target organ or can act completely independently. This risk assessment assumes that toxicity is additive; the excess lifetime cancer risks and HIs were each summed across chemicals. This assumes that the mixture of chemicals present at the site has neither synergistic nor antagonistic interactions and that all of the indicator chemicals have the same mechanism of action in the same target organ to produce the same toxic end points.

Thus, the values presented in this risk assessment are associated with significant uncertainty. The uncertainties associated with exposure scenarios and toxicity values almost certainly contribute to an over-estimate of risk. The effect of uncertainties associated with monitoring and exposure point concentration estimates data and exposure point concentrations are not known. Assuming that the field data adequately represent conditions at the new slip, we believe that the values derived in this risk assessment provide an over-estimate of constituent-related risks which may be associated with construction and operation of the new slip.

6.0 FINDINGS AND CONCLUSIONS

1. PAHs have been detected in soil samples collected from 5- and 15-foot sampling depths, and were detected in one ground-water sample from a 15-foot depth.

2. Phenols were detected in soil samples collected from 25-foot sampling depths and in ground-water samples from the 25-foot depth; however, phenols were not detected in the shallower soils.

3. PAHs are not highly soluble in water and tend to adsorb strongly to soils and organic matter, while phenols are highly water soluble and not strongly adsorbed to soils.

4. Construction of the new slip could result in the direct exposure of subsurface concentrations of PAHs to the surface water. The rate of ground-water flow into the harbor as a result of construction of the new slip is estimated to increase by only 10 percent.

5. Potential pathways of human exposure and receptors resulting from construction of the new slip include: (1) direct contact with the surrounding soils and waters of the slip by a boatyard worker or visitor to the marina; (2) direct contact with subsurface soils by a utility worker relocating the sewer line; (3) direct contact with the soil excavated from the new slip by an OMC worker or trespasser; or (4) ingestion of fish caught in the new slip by a local fisherman.

6. Exposure levels based on reasonable assumptions result in excess lifetime cancer risk levels and non-carcinogenic hazard indices within acceptable guidelines.

7. Worst-case exposure levels assuming exposure to the maximum concentrations detected in soil samples resulted in excess cancer risk levels exceeding 10^{-4} for exposure of the boatyard worker and the marina visitor.

8. Site specific soil criteria based on most sensitive potential receptors and a 1×10^{-6} excess lifetime cancer risk are:

	surficial soil	subsurface soil
cPAHs	6.0 mg/kg	480 mg/kg
tPAHs	2,900 mg/kg	85,000 mg/kg

9. Estimated sediment concentrations and surface-water concentrations in the new slip are lower than the federal water quality criteria for protection of aquatic life and interim sediment quality criteria; therefore, it is assumed that constituents detected in the soils do not pose a potential risk to aquatic organisms accessing the new slip.

10. Overall, there is no evidence that constituents detected in the soil will pose a risk to the aquatic environment of the harbor, and potential risks to human receptors are primarily associated with exposure to the maximum concentrations detected in the soils.

Respectfully Submitted

GERAGHTY & MILLER, INC.

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TABLES

Table 1. Concentrations of Constituents Detected In Soil Samples Collected from Inside and Outside of the New Slip, Outboard Marine Corporation, Waukegan, Illinois.

Location/ Constituent	Range	Arithmetic Mean	Geometric Mean
Inside Slip[a]			
5-foot Samples			
cPAHs[b]	<1.0 - 235	34	1.5
tPAHs[c]	<1.0 - 840	130	5.9
15-foot Samples			
cPAHs	<1.0 - 6	1.7	1.1
tPAHs	<1.0 - 74	15	3.2
5 and 15-foot Samples			
cPAHs	<1.0 - 235	18	1.2
tPAHs	<1.0 - 840	70	4.4
25-foot Samples			
Phenols	11 - 157	120	96
Outside Slip			
5-foot Samples			
cPAHs	<1.0 - 3110	240	13
tPAHs	<1.0 - 25,750	2200	64
15-foot Samples			
cPAHs	<1.0 - 120	6.6	0.82
tPAHs	<1.0 - 5690	280	4.1
25-foot Samples			
Phenols	19 - 289	126	100

Concentrations reported in milligrams per kilogram (mg/kg).

a Inside slip samples - S-42; S-43; S-49; S-52; S-56; S-65; S-80.

b cPAHscarcinogenic polycyclic aromatic hydrocarbons.

c tPAHstotal polycyclic aromatic hydrocarbons.

Table 2. Concentrations of Constituents Detected in Ground-Water Samples Collected in the Vicinity of the New Slip, Outboard Marine Corporation, Waukegan, Illinois.

Constituents	Monitor Wells				Arithmetic
	MW-1S	MW-1D	MW-2S	MW-2D	Mean
tPAHs[a]	1.237	--[b]	--	--	1.2
cPAHs[c]	--	--	--	--	--
Phenolics[d]	--	296	--	127.3	210

Concentrations reported in milligrams per liter (mg/L).

a tPAHs: total polycyclic aromatic hydrocarbons.
b -- below laboratory quantification limits.
c cPAHs: total carcinogenic polycyclic aromatic hydrocarbons.
d Phenolics: total phenolic derivatives detected.

Table 3. Physical and Chemical Properties of Constituents in the Slip Area, Outboard Marine Corporation, Waukegan, Illinois.

Constituents	Molecular Weight (g/mol)	Water Solubility (mg/L 25°C)	Specific Gravity	Vapor Pressure (mm Hg 25°C)	H (atm-m³/mol)	K_{OC} (ml/g)	Log K_{ow}	Fish BCF (L/kg)	Water T 1/2 (days)
cPAHs[a]	252	1.20 E-3	NA	5.60 E-9	1.55 E-6	5.50 E+6	6.06	NA	0.4
tPAHs[b]	128	31.7	1.152	0.087	4.26 E-4	9.4 E+4	3.4	10.5	~1.0
Phenolics	94.11	93,000	1.0576	.3513	3.97×10^{-7}	1.21-1.96	1.46	1.4	.62-9.0

NA Not applicable
NR Not reported.

a Represented by benzo(a)pyrene.
b Represented by naphthalene.
c Represented by phenol.

References: AES, 1988; Howard, 1989; USEPA, 1979; USEPA, 1985; USEPA, 1986a; Verschueren, 1983; Weast, 1981.

Table 4. Toxicity Summaries for Constituents in the Slip Area, Outboard Marine Corporation, Waukegan, Illinois.

Constituent	Acute Toxicity Summary	Chronic Toxicity Summary	Cancer Potential	Other
Benzo(a)pyrene	Little information on the effects of short-term or intermediate inhalation exposure to B[a]P are available. Several studies have suggested adverse effects on the skin; however these studies lacked controls, thus definitive conclusions cannot be made.	The induction of cancer is the key endpoint of toxicity following long-term exposure to benzo(a) pyrene. Hematopoietic effects have been reported in mice following subchronic oral exposure.	Long-term administration by the oral, dermal or inhalation route induces the formation of tumors in laboratory animals.	Positive results have been determined in vitro bacterial and mammalian genetic toxicology assays.
Naphthalene	Eye irritation reported at 15 ppm in air. Headache and loss of appetite from inhalation of vapors. 50 mg/kg lowest reported lethal dose in man.	Decreased spleen and thymus weights and increased lung weights observed in rats orally dosed. Retarded cranial ossification and heart development reported in offspring of rats intraperitoneally injected.	No evidence of carcinogenicity in animals or humans for oral or inhalation routes of exposure.	DNA damage reported following intraperitoneal injection.
Phenol	Gastrointestinal irritation, dermal necrosis and cardiac arrhythmias have been attributed to acute phenol exposure in humans.	Lung injury, myocardial necrosis, and hepatic and renal injury have been reported in experimental animals following subchronic inhalation exposure to phenol. These effects have not been noted in humans exposed to phenol.	No evidence in humans. Dermal application of phenol has been shown to result in tumors in mice; phenol has been shown to act as a skin tumor promoter. However, phenol is not classified as a carcinogen.	Genotoxicity has been reported in several mammalian in vitro tests.

Table 5. Toxicity Values for Constituents in the Slip Area, Outboard Marine Corporation, Waukegan, Illinois.

	RfD (mg/kg bw/d)	CPF (mg/kg bw/d)$^{-1}$
Constituent	Oral	Oral
cPAHs[a]	4.00 E-1[b]	1.15 E-1[d]
tPAHs[c] use fluoranthene	4.00 E-1[b] .005 mg/kg/d	NA
Phenolics[e]	6.00 E-1[c]	NA

a Represented by benzo(a)pyrene.
b USEPA, 1986a.
c Represented by naphthalene.
d USEPA, 1989a.
e Represented by phenol.
f IRIS, 1989.
NA Not applicable.

Table 6. Standards and Criteria for Constituents in the Slip Area, Outboard Marine Corporation, Waukegan, Illinois.

Constituent	Surface Water[a] (mg/L)	Sediment (mg/kg)
cPAHs[b]	1.2 E-3[c]	1063[c]
tPAHs[d]	6.2 E-1	1311[c]
Phenolics[e]	2.56	NA

a Federal Water Quality Criteria for protection of freshwater aquatic organisms, chronic exposure (IRIS, 1989 and USEPA, 1986b).
b cPAHs are represented by benzo(a)pyrene.
c From USEPA, 1988a. (Interim Criteria)
d tPAHs are represented by phenol.
e Phenolics are represented by naphthalene.
NA Not available.

Table 7. Exposure Pathways Analysis, Outboard Marine Corporation, Waukegan, Illinois.

Source	Release Mechanism	Transport Medium	Exposure Point	Exposure Route	Potential Receptors
contaminated soil	direct contact	direct contact	beached area	dermal, ingestion	marina visitors
	direct contact	direct contact	boatyard	dermal, ingestion,	boatyard workers
	direct contact	direct contact	south and east of new slip	dermal, ingestion, fug. dust	excavation utility worker
	direct contact	direct contact	undeveloped OMC property	dermal, ingestion fug. dust	OMC worker or trespasser
	direct contact	sediments	new slip	bioaccum- ulation	aquatic organisms
	desorption	surface water	new slip	bioaccum- ulation fish ingest.	aquatic organisms/ fisherman
contaminated ground water	discharge to surface water	surface water	new slip	dermal, ingestion	marina visitors
	discharge to surface water	surface water	new slip	bioaccum- ulation fish ingest.	aquatic organisms/ fisherman

Table 8. Exposure Dose and Risk Equations for Scenarios 1 and 2, Outboard Marine Corporation, Waukegan, Illinois.

Equation Definition

$$ExD = \frac{C_sw \times (SSA_sw \times WF \times AF \times ED \times UC1 + IRW) \times EF}{BW \times LFT} +$$

$$\frac{C_s \times (SSA_s \times DA \times AF \times ME + IRS \times ME) \times UC2 \times EF}{BW \times LFT}$$

$$CR = ExD \times cpf$$

$$HR = ExD/RfD$$

where:

AF	Absorption factor-dermal (0.10 PAHs)(USEPA, 1984).
BW	Body weight (70-kg adult; 31-kg child or 16-kg child)(USEPA, 1989b).
cpf	Cancer potency factor (assume 11.3 /mg/kg/day for cPAHs)(USEPA, 1989a).
C_s	Concentration in soils (mg/kg).
C_sw	Concentration in surface water (mg/L).
CR	Excess lifetime cancer risk.
DA	Dust adherence (1.45 mg/cm^2-hr)(USEPA, 1988b).
ED	Exposure duration (1,2,4, or 8 hrs/day).
EF	Exposure frequency (days/lifetime; assumed to be 25600 days/lifetime for non-carcinogenic effects).
ExD	Exposure Dose (mg/kg-day).
HR	Hazard ratio.
IRS	Ingestion rate - soils (10, 100 or 200 mg/day)(USEPA, 1988b).
IRW	Ingestion rate - water (0.01 or 0.2 L/day)(USEPA, 1988b).
LFT	Lifetime (25600 days/lifetime).
ME	Matrix effect - soils (0.15)(Hawley, 1985).
RfD	Reference dose (assume 0.4 mg/kg/day for tPAHs)(USEPA, 1989a).
SSA_s	Skin surface area exposed to soils (2970 or 6210 cm^2 for adult 3105 or 7000 cm^2 for child)(USEPA, 1989b).
SSA_sw	Skin surface area exposed to surface water (560 or 720 cm^2)(USEPA, 1989b).
UC1	Unit conversion 1 (10^{-6} L/mg).
UC2	Unit conversion 2 (10^{-6} kg/mg).
WF	Water flux across the skin (0.5 mg/cm^2-hr)(USEPA, 1988b).

Table 9. Average Daily Doses for Reasonable and Worst-Case Exposure Scenarios, Outboard Marine Corporation, Waukegan, Illinois.

Exposure Scenario	Reasonable		Worst Case	
	cPAHs	tPAHs	cPAHs	tPAHs
Scenario 1 (boatyard worker)	2.0×10^{-7}	7.0×10^{-5}	2.1×10^{-4}	5.6×10^{-2}
Scenario 2 (marina visitor)	6.9×10^{-9}	1.2×10^{-4}	2.1×10^{-5}	1.4×10^{-1}
Scenario 3 (utility worker)	2.5×10^{-9}	6.1×10^{-5}	2.8×10^{-6}	2.9×10^{-2}
Scenario 4 (OMC worker/ trespasser)	1.8×10^{-9}	4.2×10^{-6}	4.1×10^{-7}	1.0×10^{-3}
Scenario 5 (fish ingestion)	1.9×10^{-8}	2.5×10^{-5}	1.0×10^{-5}	5.9×10^{-3}

ADDs reported in units of mg/kg/day.

Table 10. Exposure Dose and Risk Equations for Scenarios 3 and 4, Outboard Marine Corporation, Waukegan, Illinois.

Equation Definition

$$ExD = \frac{C_s \times (SSA_s \times DA \times AF \times ME + IRS \times ME) \times UC \times EF}{BW \times LFT} + \frac{C_s \times SPM \times FIP \times BR \times ED \times UC \times EF}{BW \times LFT}$$

$$CR = ExD \times cpf$$

$$HR = ExD/RfD$$

where:

AF	Absorption factor-dermal (0.10 PAHs)(USEPA, 1984).
BR	Breathing rate (m^3/hr).
BW	Body weight (70-kg adult/ 56-kg child)(USEPA, 1989b).
cpf	Cancer potency factor (assume 11.3 /mg/kg/day fcr cPAHs)(USEPA, 1989a).
C_s	Concentration in soils (mg/kg).
CR	Excess lifetime cancer risk.
DA	Dust adherence (1.45 mg/cm^2-hr)(USEPA, 1988b).
ED	Exposure duration (2 hrs/day or 8 hrs/day).
EF	Exposure frequency (days/lifetime; assumed to be 25600 days/lifetime for non-carcinogenic effects).
ExD	Exposure Dose (mg/kg-day).
FIP	Fraction inhaled particulates (0.125)(53 FR 148).
HR	Hazard ratio.
IRS	Ingestion rate - soils (10 mg/day or 100 mg/day)(USEPA, 1988b).
LFT	Lifetime (25600 days/lifetime).
ME	Matrix effect - soils (0.15)(Hawley, 1985).
RfD	Reference dose (assume 0.4 mg/kg/day for tPAHs)(USEPA, 1989a).
SPM	Suspended particulate matter (0.075 mg/m^3)(53 FR 148).
SSA	Skin surface area exposed to soils (2970 cm^2 for adult or 2475 cm^2 for 15yr old)(USEPA, 1989b).
UC	Unit conversion (10^{-6} kg/mg).

Table 11. Exposure Dose and Risk Equations for Scenario 5, Outboard Marine Corporation, Waukegan, Illinois.

Equation Definition

$$ExD = \frac{C_s w \times BCF \times IRF \times FD \times EF}{BW \times LFT}$$

$$CR = ExD \times cpf$$

$$HR = ExD/RfD$$

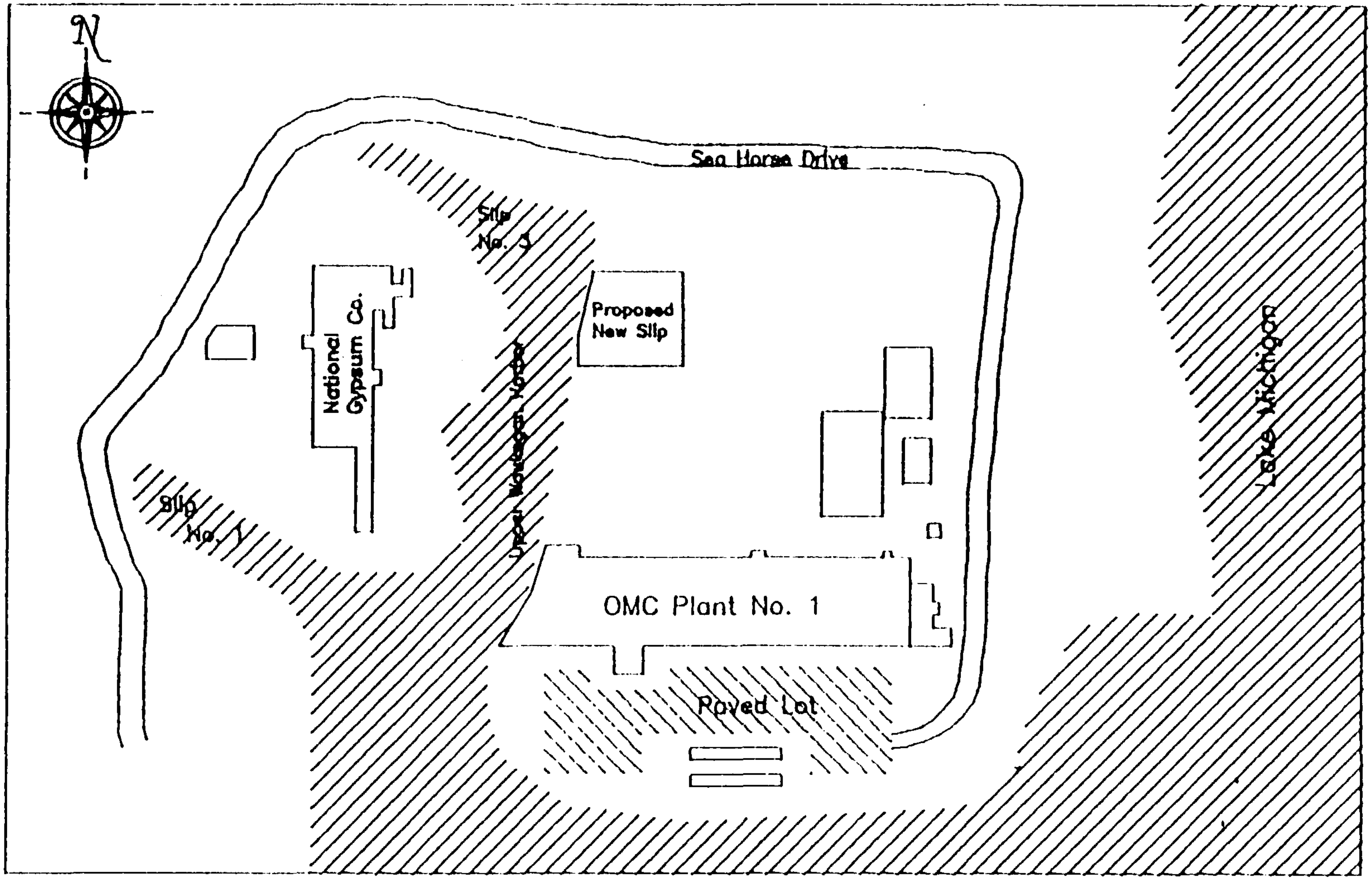
where:

BCF	Bioconcentration factor (100-1000 cPAHs; 10.5 tPAHs)(USEPA, 1986).
BW	Body weight (70-kg adult)(USEPA, 1989b).
cpf	Cancer potency factor (assume 11.3 /mg/kg/day for cPAHs)(USEPA, 1989a).
$C_s w$	Concentration in surface water (mg/kg).
CR	Excess lifetime cancer risk.
EF	Exposure frequency (assumed to be 25600 days/lifetime).
ExD	Exposure Dose (mg/kg-day).
FD	Site-related fish fraction of diet (0.10 or 1.0).
HR	Hazard ratio.
IRF	Ingestion rate - fish (0.0065 kg/day)(USEPA, 1988b).
LFT	Lifetime (25600 days/lifetime).
RfD	Reference dose (assume 0.4 mg/kg/day for tPAHs; 0.6 for phenols)(USEPA, 1989a).

Table 12. Cancer Risks and Non-Carcinogenic Hazard Indices, Outboard Marine Corporation, Waukegan, Illinois.

Exposure Scenario	Cancer Risk		Hazard Indices	
	Reasonable	Worst Case	Reasonable	Worst Case
Scenario 1 (boatyard worker)	2.3×10^{-6}	2.4×10^{-3}	1.8×10^{-4}	0.14
Scenario 2 (marina visitor)	7.8×10^{-8}	2.4×10^{-4}	3.0×10^{-4}	0.23
Scenario 3 (utility worker)	2.8×10^{-8}	3.2×10^{-5}	1.5×10^{-4}	0.073
Scenario 4 (OMC worker/ trespasser)	2.0×10^{-8}	4.6×10^{-6}	1.1×10^{-5}	0.0025
Scenario 5 (fish ingestion)	2.1×10^{-7}	1.1×10^{-4}	6.3×10^{-5}	0.015

FIGURES



GERAGHTY & MILLER ENGINEERS, INC.

FIGURE 1
OLD GM FOUNDRY PROPERTY
WAUKEGAN, ILLINOIS
NOVEMBER 28, 1989

APPENDIX A

MEMORANDUM

TO: Dan Caplice (GME-Chicago)
Frank Jones (Raleigh)

FROM: Michael P. Kladias
Glenn M. Duffield

DATE: December 13, 1989

SUBJECT: Evaluation of Ground-Water Flow Entering the Proposed Slip at the Old GM Foundry Property Waukegan, Illinois

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The Geraghty & Miller Modeling Group conducted a simple modeling study to calculate the amount of ground water that would discharge to the proposed slip. A one-layer numerical model was constructed to represent the Old GM Foundry Property site in Waukegan, Illinois. The USGS MODFLOW three-dimensional, finite-difference ground-water flow model was used to calculate the hydraulic head distribution and ground-water fluxes entering the slip and harbor.

Model boundaries included constant head cells representing the harbor, proposed slip, and Lake Michigan (Figures 1 and 3). The levels of all three water bodies were assumed to be at an elevation of 579.9 ft. A constant head boundary was also set at the north boundary of the model at an elevation of 583 ft. A hydraulic conductivity of 28.3 ft/day (0.01 cm/sec) was used throughout the model. To match observed water levels at the site, recharge was estimated by an inverse parameter estimation technique to be 11.5 in/yr. The model layer thickness was 26 ft thick.

Two model simulations were conducted. The first simulated current conditions with the proposed slip excluded from the model. The boundary conditions and hydraulic head distribution for this simulation are shown in Figures 1 and 2. The boundary conditions and hydraulic head distribution for the second simulation which included the proposed slip are shown in Figures 3 and 4.

The purpose of two simulations was to determine the increase in discharge with the addition of the proposed slip. The calculation of flux discharging to the harbor and slip was over a limited area as shown by Figures 5 and 6. The flux of ground water entering the harbor area defined by Figure 5 is 43.2 gallons per minute (gpm). The flux of water entering the harbor and proposed slip area defined by Figure 6 is 47.7 gpm. The addition of the proposed slip results in a 4.5 gpm increase in ground water discharge. The flux entering just the proposed slip area (represented by six cells in the model) is 13.8 gpm.

GERAGHTY & MILLER, INC.
Environmental Services
MODELING GROUP

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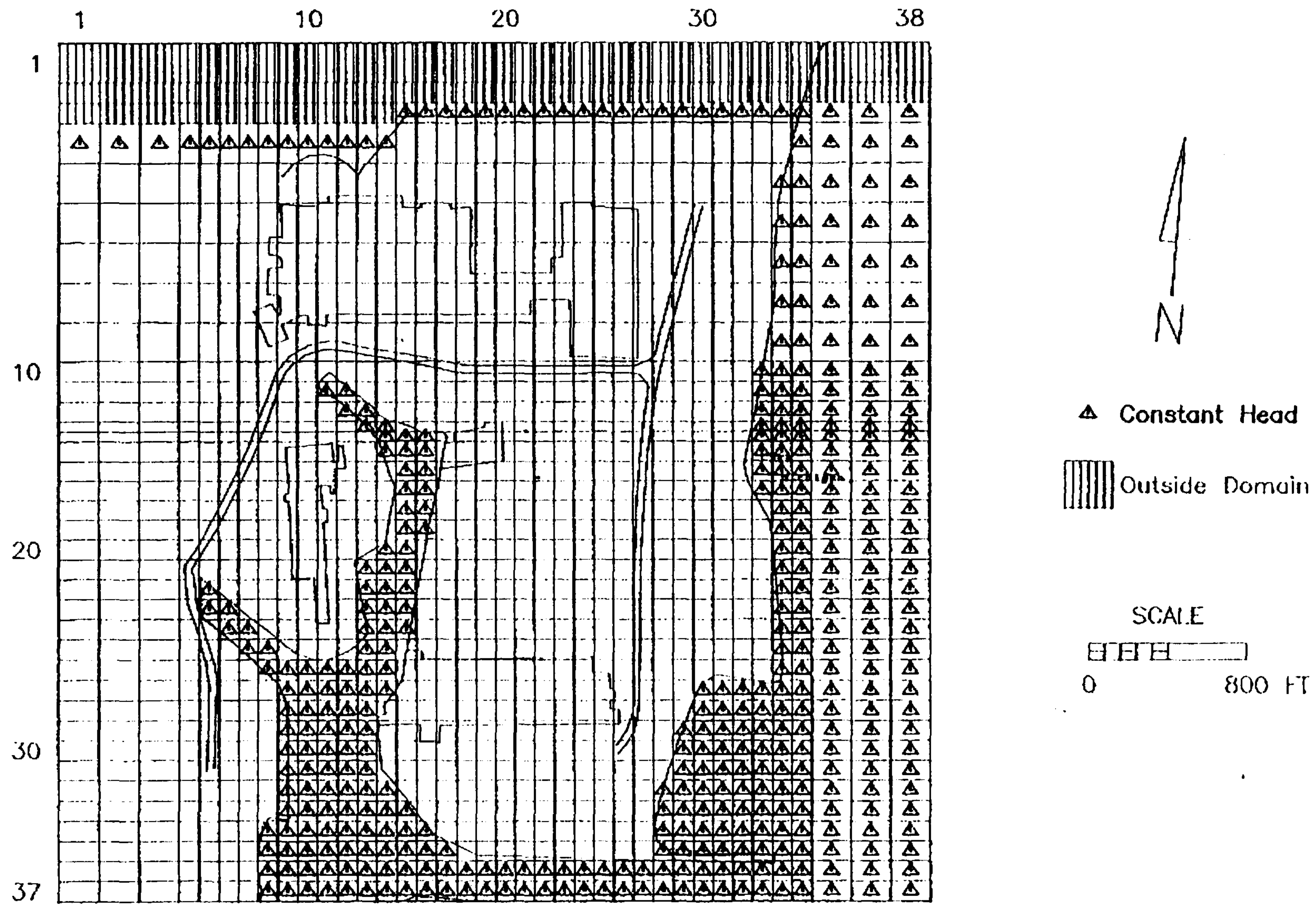
FIGURE 1.



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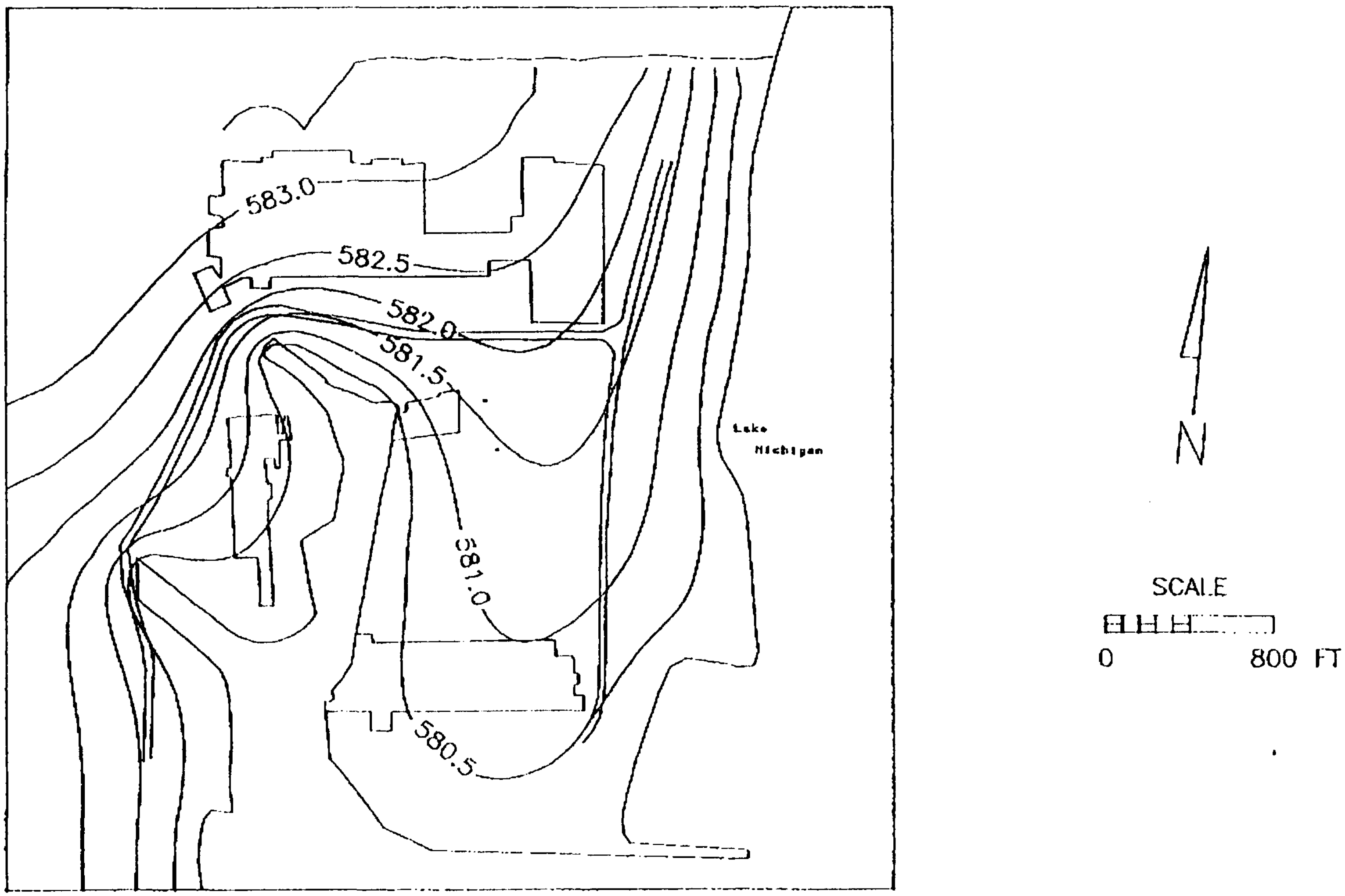

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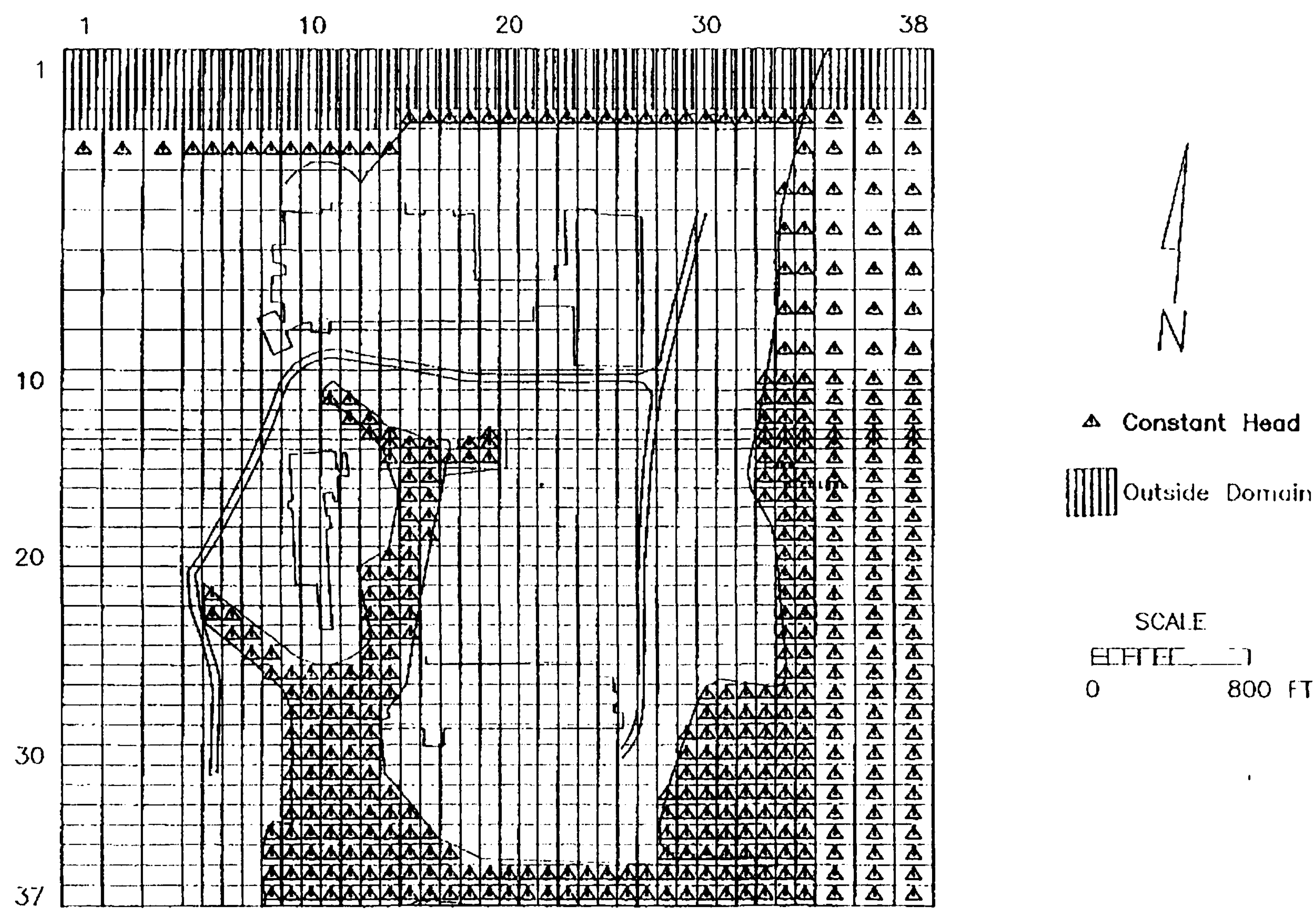
	PREPARED BY:	C.F. NAME:	DATE:
	PROJECT MGR.:		

FIGURE 3.



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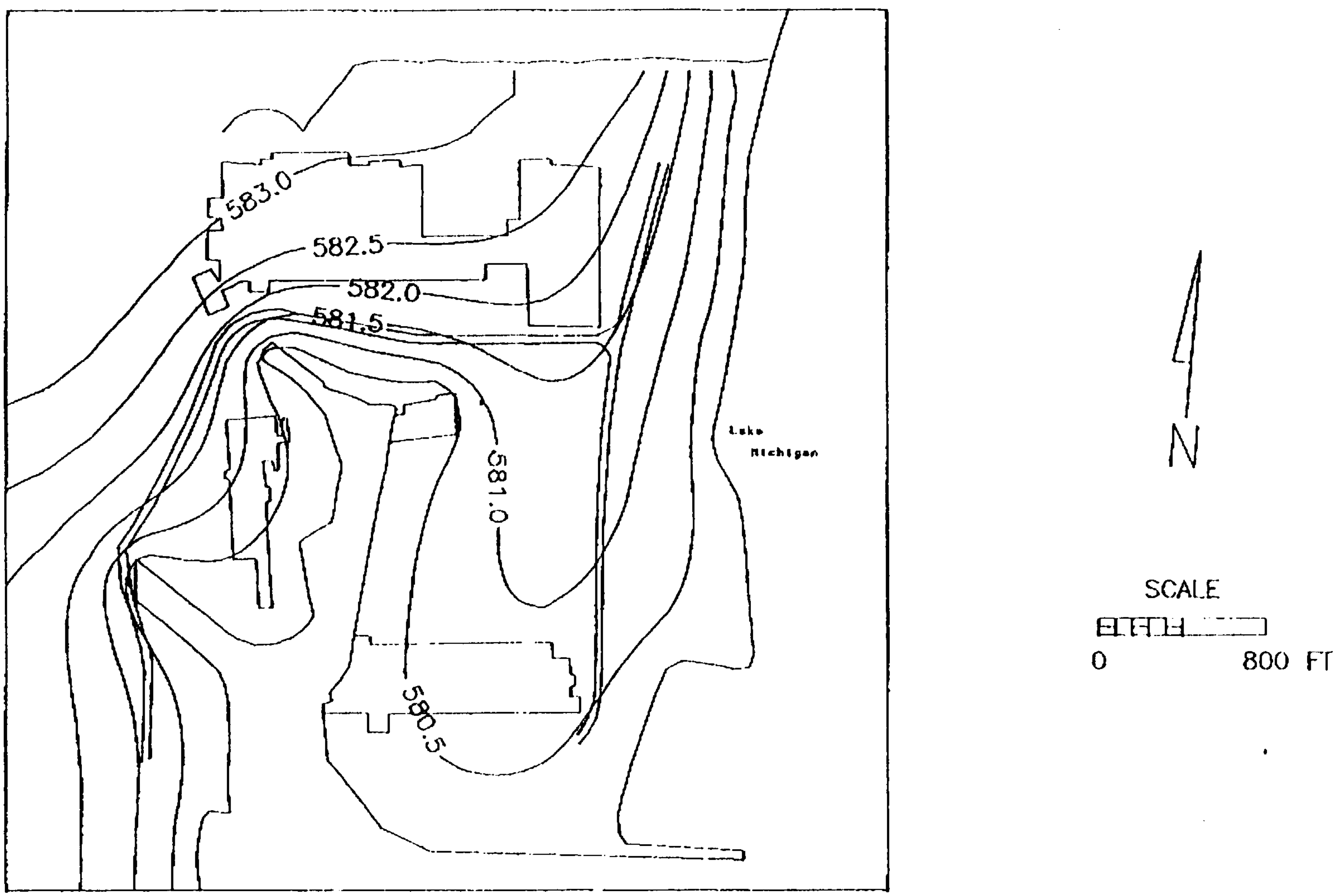
PREPARED BY:	C.F. NAME:	DATE:	
PROJECT MGR:			



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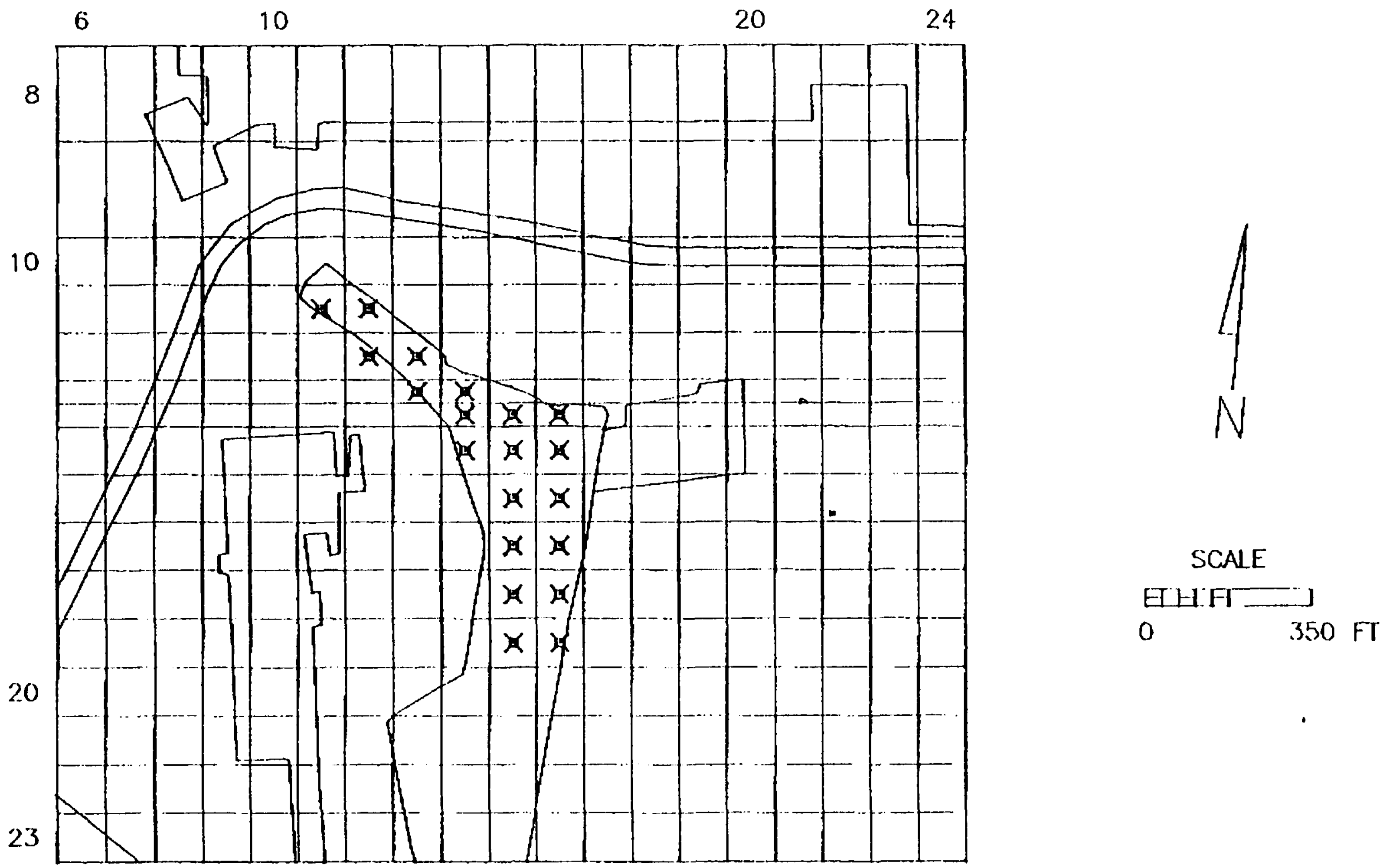
GERAGHTY & MILLER, INC. Environmental Services MODELING GROUP	COMPILED BY:	FILE INDEX:	SCALE:	FIGURE 5
	PREPARED BY:	C.F. NAME:	DATE:	
	PROJECT MGR.:			



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COMPILED BY:	FILE INDEX:	SCALE:	FIGURE 6
PREPARED BY:	C.F. NAME:	DATE:	
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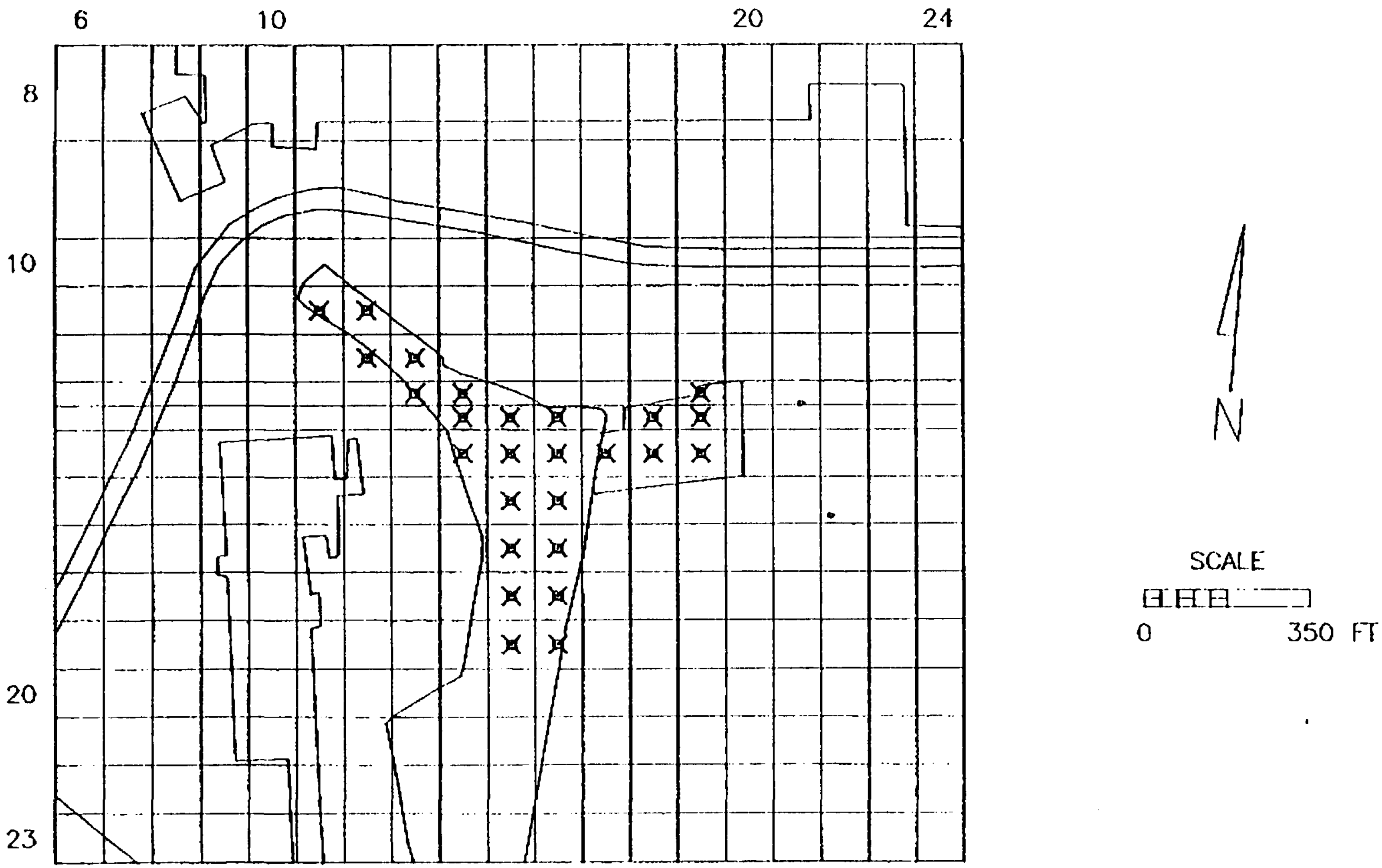

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